T.2 Research using Indus-1

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Beamlines on Indus-1

Indus-1 has four bending magnets of field 1.5 Tesla and radius of 1 meter. Each bending magnet vacuum chamber has two ports at 10° and 50°. Beamlines can be drawn from only three bending magnets as the fourth magnet is close to the injection septum magnet. From these three bending magnets, it is possible to tap six beamlines. Figure T.2.1 gives the schematic representation of the experimental hall showing various locations of beamlines. At present four beamlines are operational. Two more beamlines are in the advanced stage of commissioning and will be operational soon. The characteristics of these beamlines are given in Table T.2.1. These beamlines are as follows:

Table T.2.1: Beamlines on Indus-1

Beamline	λ - Range	Monochromator	Organization	Status
Reflectivity	40 - 1000Å	TGM	CAT, Indore	Operational Nov,2000
Angle integrated PES	60 - 1600Å	TGM	IUC, Indore	Operational Nov,2000
Angle resolved PES	40 - 1000Å	TGM	BARC, Mumbai	Commissioned in Dec,2002
Photo physics	500 - 2500Å	Seya-Namoika	BARC, Mumbai	Commissioned in March,2003
High resolution VUV	400 - 2500Å	Off-plane Eagle	BARC, Mumbai	Construction
Photo absorption (PASS)	30- 100 Å	SX700	BARC, Mumbai	Construction

The reflectivity beamline is designed taking 10 mrad as horizontal and 5 mrad as vertical divergence from bending magnet DP2 of Indus-1. The premirror is a toroidal mirror to focus the SR beam on to the entrance slit of the monochromater. The beam is incident at 4.5° to the mirror surface. This mirror is gold coated and has a demagnification ratio of 2:1. The monochromator used in this beamline is a toroidal grating monochromator (TGM) type. The entrance slit of the monochromator can be changed in horizontal direction from 0.4mm to 3mm in four discrete steps, whereas the vertical slit is adjustable from 0.0 to 1.8mm continuously. The deflection angle at the grating is 162°. The three interchangeable gratings (200, 600 and 1800 lines/mm) cover the wavelength from 40Å to 1000Å. The average spectral resolving power for this wavelength range is 500. The post mirror is also a toroidal type to refocus the monochromatic beam on to the target, which is kept at a distance of 1.8meters from the center of the mirror. The demagnification ratio is 1:1. The typical spot size is 1mm (h) x 1mm (v).

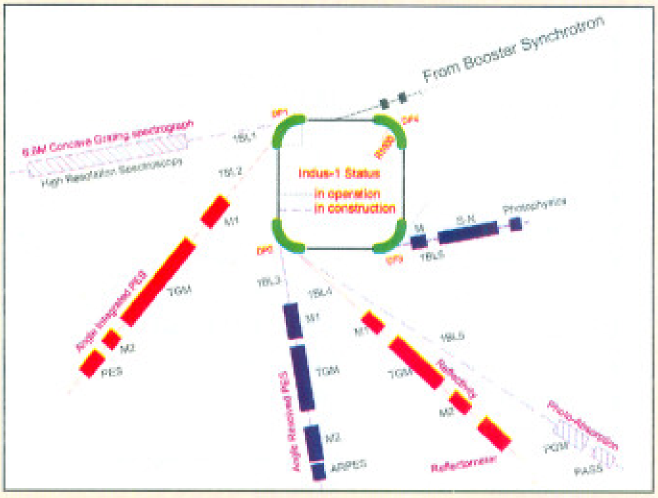

Fig. T.2.1 Experimental beamlines on Indus -1

The measured photon flux using the three gratings is given in fig.T.2.2. The experimental station on this beamline is a multipurpose reflectometer. It operates in the vacuum of 1×10^{-8} mbar and has a two-axis goniometer with independent and coupled rotation of sample and detector with an angular resolution of 2.5mdeg. In between the beamline and the reflectometer a differential pumping station is installed as the beamline is under vacuum of 10^{-9}mbar. It is possible to set the reflectometer in either s or p polarization geometry. The detectors that are used are either Si or GaAsP photodiodes. The details can be seen in Nandedkar et. al.[1]

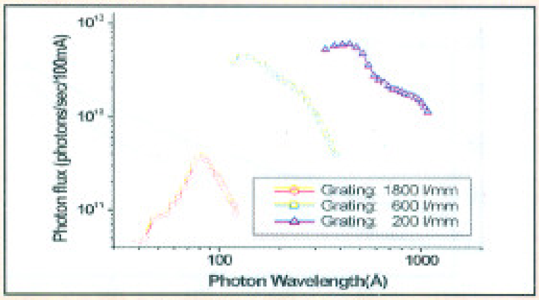

Fig. T.2.2 Photon flux

Angle Integrated PES beamline is built by Choudhary et.al.[2] of IUC-DAEF, Indore. This is again a

TGM based beamline on the bending magnet DP1, with toroidal mirrors as pre and post focusing optics. The acceptance of the beamline is 10mrad (h) x 4mrad (v). The entrance arm length of the monochromator is 1500mm and the exit arm length is 2634mm. The wavelength that can be covered by three interchangeable gratings is 60 to 1600Å. The experimental station is an indigenously built angle integrated photoelectron spectrometer. It comprises of an ultra high vacuum chamber in which a 100mm radius hemispherical analyzer and a channeltron detector are housed. The chamber is equipped with a twin anode x-ray source (Al K_α and Mg K_α lines), sample manipulator with x-y-z motors, sample heating (900°C) and sample cooling (liquid nitrogen temperature) facilities. The sample preparation chamber has a diamond file to scrub the sample surface and a quick load lock system with a magnetically coupled transfer rod. The measured energy resolution of the electron analyzer is 800meV.

An angle resolved photoelectron spectroscopy beamline is built by Bhabha Atomic Research Centre (BARC), Mumbai on the bending magnet DP2. It is based on a toroidal grating monochromator. The UHV chamber of the spectrometer contains both angle resolved and angle integrated electron analyzers. The chamber also has low energy electron diffraction and an Auger probe to determine the orientation of single crystals, a sample manipulator and an argon-ion sputter etch gun for in situ sample cleaning.

Photophysics beamline is also built by BARC on the bending of magnet DP3. The wavelength that can be covered by using a 1-meter Seya-Namioka monochromator with a spherical grating (2400 l/mm, gold coated) is 500Å to 2500Å. The beamline acceptance is 41(h) x 5.6(v). The experimental station consists of a 250mm diameter UHV cell for absorption and emission spectroscopy experiments in gas phase and an UHV chamber and a sample holder for solid samples.

In addition, two more beamlines are under fabrication stage. These are :

High resolution spectroscopy beamline with a 6.65meter spectrometer in the off axis eagle mount having gold coated concave gratings, and

Photo absorption spectroscopy beamline based on a plane grating monochromator to study the absorption edges in the energy range 100-800eV. These beamlines will take a while before they are set up on Indus-1.

Research work

Using various beamlines, the following research work has so far been carried out:

Optical constants of silicon and silicon dioxide

With the reflectivity beamline, angle dependent reflectance measurements in the soft x-ray region on etched silicon and silicon dioxide wafers were carried out. From these data, the optical constants δ and β were derived in wavelength range 80-200Å. The values for silicon obtained compared with the results of Soufli and Gullikson[6] For silicon dioxide the data obtained using Indus-1 match reasonably well with the tabulated data of Henke et al.[7], and the measured data by Filitova et.al.[6] in the wavelength range typically up to 160Å. However above this wavelength, the measurements performed by them show a downward trend from the data of Henke et al[8]. whereas the measurements performed on Indus-1 show an upward trend. This is illustrated in fig. T.2.3.

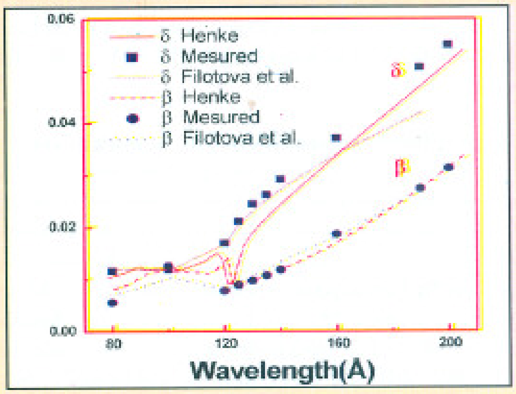

Fig. T.2.3 Optical constants for silicon dioxide sample

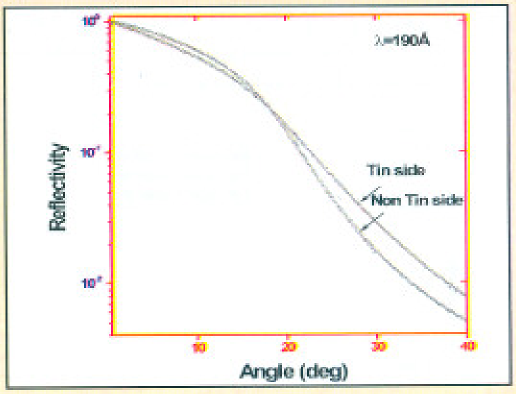

Fig. T.2.4 Soft x-ray reflectivity spectra of two faces of float glass

Diffusion of tin on optical behavior of float glass

Using the reflectivity beamline on Indus-1, the optical response of two sides of float glass is studied. The optical parameters delta and beta are determined using angle dependent reflectance measurements in the wavelength range 80-200Å. While preparing the float glass from the melt, the surface that is in contact with molten tin will have some tin diffused in, whereas the opposite surface, which is not in contact with tin, will have no tin present The optical constants are very sensitive to the presence of impurities on the surface and the sub-surface region. It is therefore possible that the optical response of a float glass will be different for the top and the bottom surface (tin side). Since the diffusion of tin will be very small, it will be possible to measure optical response using soft x-rays from Indus-1. Such measurements were performed on float glass sample using Indus-1 in the wavelength range 80-200Å. The experimental results show that the optical constants of the non-tin side surface follow the same trend as data tabulated by Henke et.al. with an upward shift in delta value. The delta value obtained form the measurements on the tin side is higher than the delta value measured form the non- tin side surface. The effect is attributed to the presence of tin which will change the surface density. The typical reflectivity profile for both sides at wavelength of 190Å is shown in the fig. T.2.4.

Soft X ray reflectivity studies in Mo/ Si multilayers

Soft x-ray reflectivity measurements of Mo/Si multilayers were also studied on the reflectivity beamline. Angle–dependent reflectivity spectrum of Mo/Si multilayer deposited on a float glass substrate of period 89Å (30 Mo/59Si) with 5 layer pairs is shown in fig. T.2.5. Measured spectrum is shown by circles whereas the dotted line represents calculated spectrum using a two-layer model with no inter -diffused layer, and the continuous spectrum assuming a four-layer –model. It is clear that the four -layer models give the best fit. The four -layer model assume two inter layers formed at interfaces like Mo on Si and Si on Mo. An asymmetry at the two interfaces viz. Si-on-Mo and Mo-on-Si was considered for good model fitting.

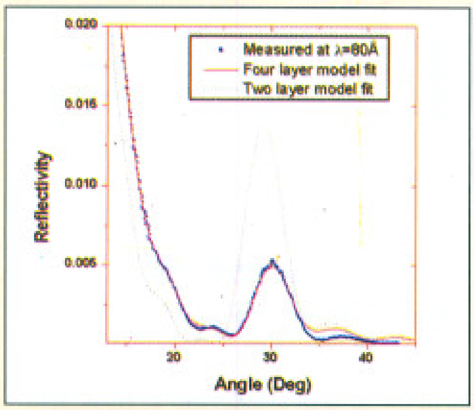

Fig. T.2.5 Reflectivity spectrum of Mo/Si multilayer measured at λ=80Å

These multilayers were also characterized using cross sectional electron microscopy. A cross sectional electron micrograph is shown in fig. T.2.6. It is clear form the photograph that the multilayer has a distinct layered structure and the roughness increases from the bottom to the top stack.

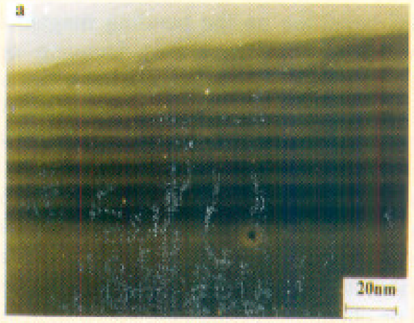

Fig. T.2.6 Bright field cross sectional micrograph of Mo/Si ML

Photoelectron spectroscopy of $Li_{1-x}Nb_xO$

On the angle integrated photoelectron spectroscopy beamline of IUC, $Li_{1-x}Nb_xO$ with x=0, 0.2 & 0.5 core levels were studied. It has been observed that even with the doping of 0.5 of Li, O-2p and Ni-3d peak positions remain unchanged. Analysis of the results indicated that Li doping creates holes in the oxygen 2p confirming the earlier conclusions.

In the angle resolved photoelectron spectroscopy beamline, standard spectrum of gold was recorded. The experimental station is fabricated in house. The first results are encouraging. Efforts are on to study and improve the spectrometer resolution by optimizing various parameters. Photophysics beamline is just commissioned and experiments will start soon.

References

1. Nandedkar R.V, Sawhney K.J.S, Lodha G.S, Verma A, Raghuvashi V.K, Sinha A.K, Modi M.H and Nayak M, Current Science 82 (3) 298-304,(2002.)
2. Chaudhary S.M, Phase D.M, Wadikar A.D, Ramesh G, Hegde M.S and Dasannacharya B.A Current Science 82 (3) 305-309, (2002)
3. Jha S.N, Das N.C, Rao S.V.N.B, Sinha A.K, Bandhopadhyay K, Jagannath M, Korgaonkar A.V and Bhushan K.G. Conf. Proc Solid State Physics Symp. 44, 585-587. (2003).
4. Roy A.P., Spectroscopy prospective and frontiers, Roy (Ed), . Narosa Pub. House, New Delhi 317-320, (1997)
5. Tripathi Pragya, Lodha G.S, Modi M.H, Sinha A.K, Sawhney K.J.S and Nandedkar R.V., Optics Comm 211,215-223,(2003).
6. Soufli R and Gullikson E.H, Appl Optics 36, 5499-5507,(1997).
7. Henke B.L, Gullikson E.M and Davis J.C, Atomic Data and Nuclear Data Tables 54, 181-343,(1993)
8. Filitova E.O, Lukyanov V.A, Barchewitz R, Andre J.M, Idir M and Stemmler Ph.,. J Phys. Condense Matter 11, 3355-3370, (1996)
9. Mohhamad H. Modi, Gyanendra S.Lodha, Kawaljeet S. Sawhney and Rajendra V.Nandedkar Communicated to Applied Optics.
10. Modi M.H, Lodha G.S, Nayak M, Sinha A.K and Nandedkar R.V Physica B 325, 272-280,(2003).
11. Bannerjee A., Chaudhary S.M., Phase D.M., Dasannacharya B.A., Nucl Instru and Methods B-199,406-410(2003).